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BIOLOGICAL EVALUATION
OF
SULFUR OXIDE EMISSIONS
IN THE
SILVER BAY AREA
SITKA, ALASKA

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by

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Defoliation and death of trees in the vicinity of the Alaska Lumber and Pulp pulp mill at Silver Bay has been noted since the early 1960's. As there was considerable insect activity in the mill area throughout the last decade the damage was attributed to insects. A blackheaded budworm outbreak occurred in 1963 followed by a hemlock sawfly outbreak in 1967. In the early 1970's there was spruce aphid activity followed by some bark beetle attack on aphid damaged trees.

The first examination attributing tree mortality to sulfur dioxide injury was in October of 1970. At this time it was noted that the foliar symptoms of the distressed trees indicated SO_2 injury. It was also noted that Alaska-cedar, as well as hemlock and spruce, was dying. There was no evidence of other diseases and no insects had attacked cedar.

In October of 1973 foliage samples were collected near the pulp mill and, for background, at Miles 10 and 12 on the road north of Sitka. These foliage samples were analysed for sulfur content.

The results of the analyses showed significantly higher percentages of sulfur in foliage near the mill than were found in the background samples. The percentages of sulfur in the background samples was negligible.

I. Technical Information

Causal Agent: Sulfur oxides.

Host Trees: *Tsuga heterophylla* (Raf.) Sarg., western hemlock; *Chamaecyparis nootkatensis* (D. Don) Spach, Alaska-cedar; and *Picea sitchensis* (Bong.) Carr., Sitka spruce.

Location: Area adjacent to the Alaska Lumber and Pulp pulp mill in Silver Bay near Sitka.

Type of Damage: Acute and chronic fume injury caused by oxides of sulfur. The injury is expressed as a discoloration of needles (yellowish to reddish-brown), shrinkage of tissues, and defoliation giving the trees a thin, sparse-foliaged, weak appearance.

II. Procedure: Foliage samples were collected from each of the three tree species adjacent to the mill and for a backgound sample at Miles 10 and 12 on the highway north of Sitka.

The foliage samples were returned to the laboratory and dried. The needles were removed, bagged and labeled according to species and location. The samples were then sent to WARF Institute, Inc. of Madison, Wisconsin for analysis. Analyses were made for percent sulfur and percent sulfate.

III. Results of Analysis

Tree Species and Sample Location	Date Collected	Foliar Concentrations *	
		Sulfur (%)	Sulfate (%)
Sitka Spruce Mile 12, Background	10-12-73	0.04	0.12
Sitka Spruce (1) Silver Bay	10-12-73	0.29	0.87
Sitka Spruce (2) Silver Bay	10-12-73	0.24	0.72
Western Hemlock Mile 12, Background	10-12-73	0.07	0.21
Western Hemlock (1) Silver Bay	10-12-73	0.31	0.93
Western Hemlock (2) Silver Bay	10-12-73	0.39	1.17
Alaska-Cedar Mile 10, Background	10-12-73	0.04	0.12
Alaska-Cedar (1) Silver Bay	10-12-73	0.23	0.69
Alaska-Cedar (2) Silver Bay	10-12-73	0.26	0.78

* Methods of Analysis. Sulfur: Soil Society of America Proceedings, 29,71 (1965)

IV. Discussion

Sulfur dioxide gas can cause acute and/or chronic injury to trees. Acute injury is observed after exposure to short-term high levels of the gas or when a tree is very sensitive. Acute injury in conifers causes a tan to reddish-brown discoloration indicating death of all or part of the needle. In some instances the needle will have a banded appearance which is more typical of injury occurring in the winter when the trees are relatively dormant.

Chronic SO_2 injury usually produces a general yellowing of the needles before they are shed prematurely. The tree's crown has a sparse thin appearance. In time the tree is greatly weakened and growth is reduced.

There is no clearcut demarcation between acute and chronic injury, but rather an intergradation of symptoms.

The effect of SO_2 on the trees varies based on concentrations, distance from source, length of time of accumulation, and within and among tree species as to susceptibility.

The concentration of SO_2 to which a tree is exposed depends first on the concentration at the source and then on degree of dilution in transit. The extent of dilution depends on length of time between emission and deposition. Meteorological conditions exert the greatest influence on the dispersal and removal of air pollutants. Winds or vertical turbulence are necessary - without these, SO_2 accumulates in concentrations which may easily become toxic. As SO_2 readily goes into solution in water, rainwater is very effective in removing it from the atmosphere.

The SO_2 enters the foliage mainly through stomata. Once within the needles, sulfur is distributed rather uniformly according to the normal distribution of sulfur-bearing proteins. The sulfur content of leaves is useful in obtaining a general idea of SO_2 concentration increases once normal levels are known and to define the scope of the area which has been exposed.

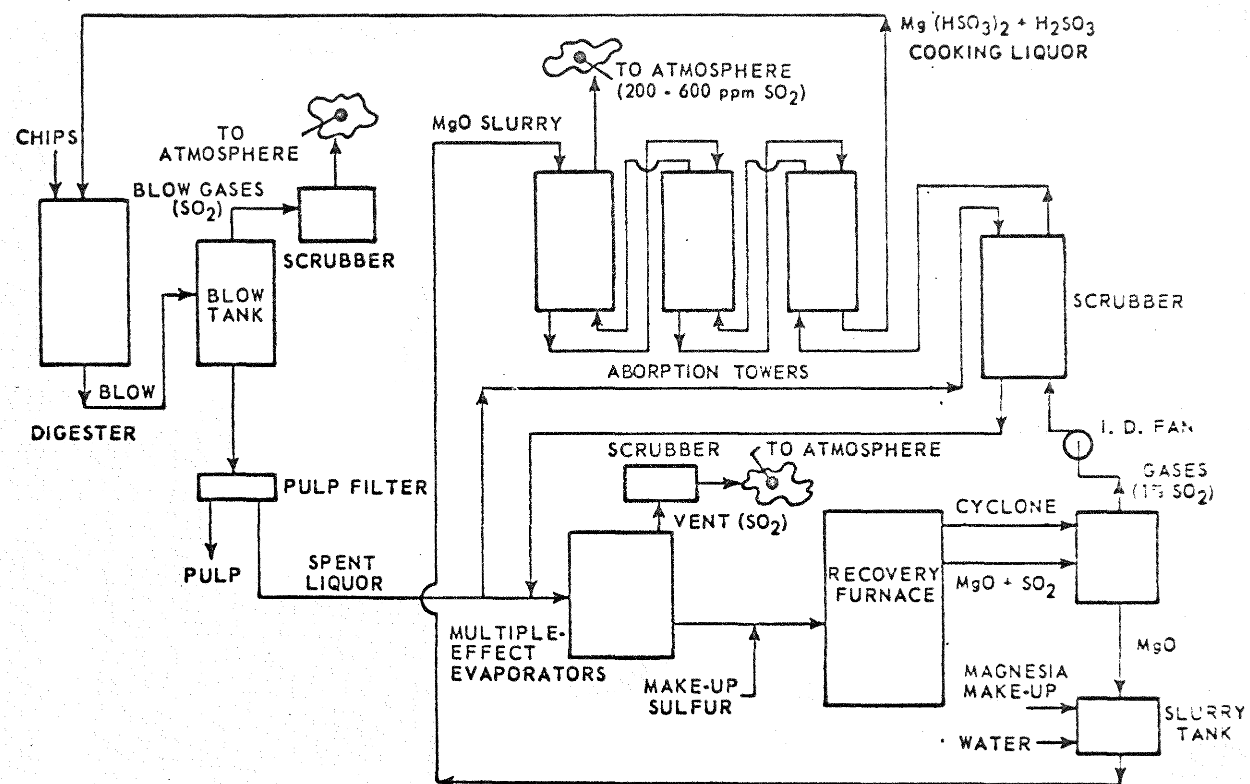
Levels of SO_2 required to be injurious depend on sensitivity and metabolic activity, time of day, time of year, and rate of absorption. Threshold concentrations of SO_2 can cause some growth reduction with no visible markings. Severely injured trees can gradually recover after cessation of exposure to the SO_2.

Sensitivity of plant materials to SO_2 is affected significantly by temperature, relative humidity, soil moisture, light intensity, nutrient level, and by sulfate content of the soil. The plant susceptibility increases with temperature (greatest at temperatures over 40^oF), with increased relative humidity, increased soil moisture, increased light intensity, and with a decrease in nutrient supply. Young trees are more resistant to SO_2 injury than mature trees with the exception of conifer seedlings which are very susceptible.

Sulfur dioxide is very soluble in water and in the presence of mist and rain is converted to sulfuric acid. This sulfuric acid mist can cause visible injury to moist leaves. In addition to causing visible leaf injury there is the possibility over long periods of time, of changing pH values in the soil.

Point sources of SO_2 are normally the major cause of plant damage and almost always the cause of acute injury. Point source examples are smelters, refineries, large coal burning power plants, plants burning high sulfur residual oils, sulfate and sulfite process pulpmills. The point source we are considering in this evaluation is a sulfite process mill which uses an acid-base process for dissolving the lignin bonding material from the wood chips. The cooking liquor is produced by reacting SO_2 with a base (magnesium in this instance) in an absorption device. A bisulfite solution is formed and used as a cooking liquor for the wood chips in a digester. Economical operation of the sulfite process requires efficient recovery of SO_2 from combustion gases as concentrations of over 1 percent SO_2 result from liquor combustion. At a recovery efficiency of 90 percent, 20 pounds of SO_2 per ton of pulp is emitted. For a 600 ton per day mill this would mean that 12,000 pounds of SO_2 (664,200 cu. ft.) per day is emitted. A recovery of over 98 percent is possible with three-stage venturi absorption.

Fig. I. A typical magnesium-base chemical pulping recovery process illustrating points of SO_2 loss to the atmosphere. *



* From: Control Techniques for Sulfur Oxide Air Pollutants. National Air Pollution Control Administration. Publication No. AP-50.

Dead trees on the slope adjacent to the pulp mill are examples of the result of continued acute SO_2 injury. The foliage of the trees surrounding this slope exhibits typical symptoms of chronic SO_2 injury - a general yellowing of the needles and premature defoliation giving the tree's crown a sparse, thin appearance. In times past this has been further complicated by insect feeding on hemlock and to a limited extent spruce which also results in a sparse weak appearing crown. A combination of insect and SO_2 damage probably puts a great strain on the physiological processes of the trees. Where symptoms of acute SO_2 injury occur there is no foliage suitable for insect feeding. The location of slope adjacent to the mill and the direction of the prevailing winds set the stage for acute injury in this area. Inversions in turn extend the area in which chronic injury occurs.

A more efficient recovery of SO_2 would reduce damage to trees in Silver Bay. Recovery of SO_2 also means recovery of SO_2 from steam and power boiler emissions. If residual oils are used to fire the boilers it is possible for more SO_2 to be emitted there than from the pulping process. The reason for this is that in refining high sulfur oils the sulfur is driven toward the residual portion.

Conifers are more susceptible to SO_2 injury than are broad leaved trees. Of the conifers western red cedar and western hemlock are among the most susceptible. Ambient SO_2 levels as low as 0.01 ppm have caused significant damage to conifers. In spite of this susceptibility to SO_2 damage conifers can possibly recover when no longer exposed to the gas.

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